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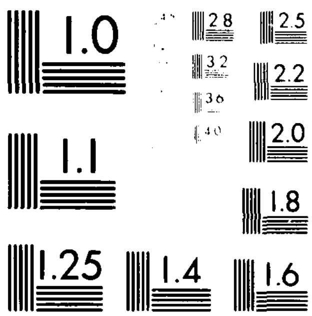

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MODERNIZATION OF ROUGH-TERRAIN CRANE

by

George Kuzma

November 1979

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U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND MERADCOM

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: 2286	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): 6 MODERNIZATION OF ROUGH-TERRAIN CRANE	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 George Kuzma	8. CONTRACT OR GRANT NUMBER(s): 12) 31
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Mechanical & Construction Equipment Laboratory, US Army Mobility Equipment Research and Development Command; Fort Belvoir, Virginia 22060	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Mechanical & Construction Equipment Laboratory, US Army Mobility Equipment Research and Development Command; Fort Belvoir, Virginia 22060	12. REPORT DATE: 11) Nov[redacted]79
	13. ~~NUMBER OF PAGES~~: 31
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 14) MERADCOM-2286	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

- Crane
- Rough-Terrain Crane
- Materials-Handling Equipment
- Power Train
- Hydraulic
- Extendible Outriggers

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Report summarizes the redesign of the 20-Ton, Rough-Terrain Crane to increase lifting capacity and stability and to broaden the procurement base by testing a hydraulic upperworks and new power train. The prototype hydraulic crane met the design and performance requirements of MIL-C-52341.

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SUMMARY

This report summarizes efforts to modernize the design of the 20-Ton, Rough-Terrain Crane, which dates back to 1964. These efforts included addition of extendible outriggers to improve stability; use of a hydraulic superstructure in place of the mechanical superstructure in accordance with Industry and Army trends; and incorporation of an alternate power train to broaden the procurement base. Both the redesigns and tests are described.

The report concludes that the extendible outriggers improve stability; that it is feasible to provide a hydraulic crane with a capacity up to 25 tons through modification of the Technical Data Package; and that the alternate power train is suitable.

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ILLUSTRATIONS

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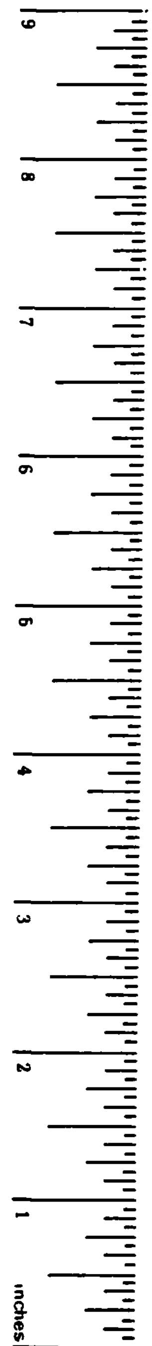
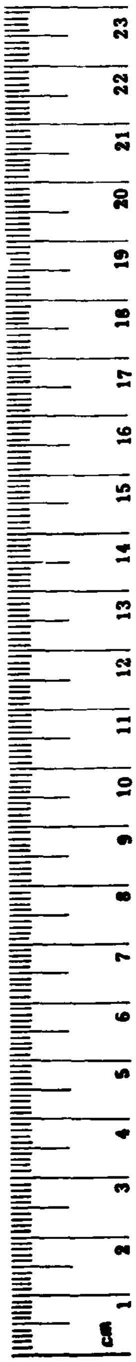
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	metric tons	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	L
pt	pints	0.47	liters	L
qt	quarts	0.95	liters	L
gal	gallons	3.8	liters	L
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

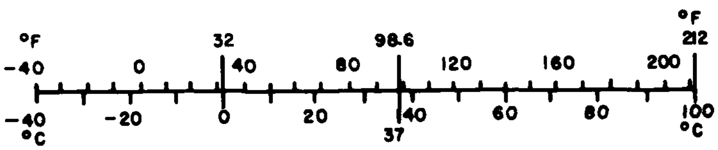
* 1 in = 2.54 cm (exactly).





Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10 000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	metric tons (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
L	liters	2.1	pints	pt
L	liters	1.06	quarts	qt
L	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



MODERNIZATION OF ROUGH-TERRAIN CRANE

I. INTRODUCTION

1. **Background.** The 20-Ton, Wheel-Mounted, Rough-Terrain Crane currently in use by the Army consists of a modified commercial mechanical superstructure mounted on a Military-design carrier (Figure 1). The crane was procured in 1964 and fielded in 1968; 1,115 cranes, excluding developmental prototypes, have been procured under three contracts using Military Specification MIL-C-52341.

2. **Purpose and Scope.** The crane, as fielded, meets all established military requirements. However, the basic design dates back to 1964 except for changes made to replace obsolete components and to improve producibility. Extensive field experience, changes in the state-of-the-art in the crane industry, and the availability of alternate components dictated that modernization of the crane design was in order, resulting in the redesign and testing covered in this report. This modernization consisted of three major changes: addition of extendible outriggers to improve lifting stability, replacement of the mechanical superstructure with a hydraulic superstructure, and replacement of the power train components with alternate components.

II. INVESTIGATION

3. **General.** Engineering, design, and fabrication were performed by Value Engineering Company (VECO) of Alexandria, Virginia, except for that of the superstructure which was accomplished by Pettibone Corporation of Rome, New York. Testing was conducted at Fort Belvoir, Virginia, by MERADCOM and supplemented by strain gage tests conducted by Pettibone Corporation.

4. **Extendible Outriggers.** The crane as fielded is equipped with fixed outriggers. Numerous complaints were received from field users concerning the stability of the crane when rated loads were being lifted over the side, even though the rated loads are within the industry standard of 85 percent of tipping load. (This is a psychological problem caused by the fact that the far-side outriggers came out of contact with the ground when lifting rated loads.) Therefore, a study was made to determine what could be done to increase lifting stability.

Constraints on the study were that overall dimensions of the crane could not be increased, modifications to the carrier were to be held to a minimum, and weight increase was to be kept to a minimum. These constraints ruled out such obvious approaches as increasing the superstructure counterweight or increasing vehicle

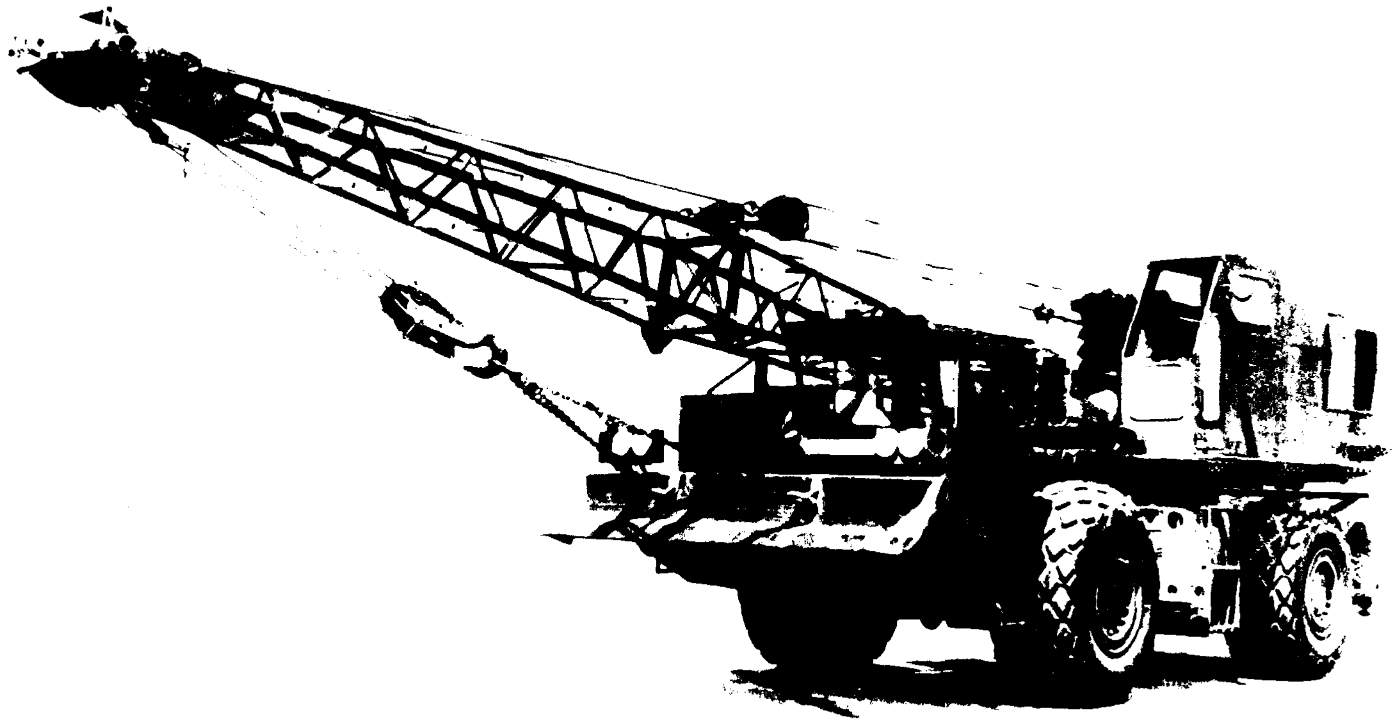


Figure 1. Standard 20-ton, rough-terrain crane.

width to obtain the desired increase in tipping moment capacity to increase stability over the side. Therefore, the study concluded that the most suitable method would be incorporation of extendible outriggers.

Two types of extendible outriggers were considered: a swing-down arm design and an extendible (telescoping) beam design. Preliminary investigations indicated that the swing-down arm outrigger would be the best approach because incorporation would require the least modifications to the carrier frame and existing hydraulic controls could be used; whereas, the extendible-beam type would require significant frame redesign and would require changes to existing hydraulic controls because two cylinders would be required rather than one. However, subsequent layout drawings showed that the swing-down arm design could not be used because the arm would not clear the carrier engine. Therefore, this design was discarded. Layout drawings of the extendible-beam mechanism showed that with frame modification the retracted beam could be nested under the engine oil pan and front axle drive shaft. Therefore, detail design was accomplished on this type of outrigger.

A 90-inch outrigger extension was chosen. The design makes maximum use of existing components in that the existing outrigger cylinders and float pads are usable. During the course of the outrigger design, it was decided to incorporate controls on the rear of the crane enabling the operator to extend and lower the outriggers while standing on the ground on either side of the crane. (With the existing design, the outriggers can be lowered only from the cab. The operator cannot see all of the outriggers when lowering them.)

After completion of the design, the new outriggers and controls were fabricated, bench tested, and installed on a standard 20-ton rough-terrain crane.

5. **Superstructure.** In recent years, there has been a strong trend in the commercial crane industry, in the 30-ton and below class, to go from mechanical superstructures with lattice-type booms to hydraulic superstructures with telescoping-beam booms. In addition, many companies are now manufacturing four-wheel cranes for off-road use, all of which have hydraulic superstructures. The Army has followed this trend in that all recent procurements of 25-ton truck-mounted cranes, intended to replace 20-ton units, have been with hydraulic superstructures. In comparison to the mechanical superstructure, the hydraulic superstructure offers the advantages of smoother operations while raising, lowering, and swinging; ability to vary boom lengths without the addition or subtraction of boom sections; and, possibly, less overall maintenance. The only drawback to the hydraulic superstructure is that it is less suited for clam-shell and dragline operations.

As a result of the Industry and Army trends, it was considered appropriate to investigate the use of a hydraulic superstructure for the crane as a part of the modernization of the crane design. Since the Army was also increasing the crane size from 20 tons to 25 tons on truck-mounted cranes, it was further decided that a 25-ton superstructure should be evaluated, especially since an evaluation of the characteristics of a 25-ton hydraulic unit would also be applicable to a 20-ton unit. An additional side benefit was that the 25-ton capacity would enable the crane to handle standard military containers weighing up to 50,000 pounds.

For economy reasons, a Government-owned Pettibone 20-ton hydraulic superstructure was chosen for use in the evaluation. Pettibone Corporation modified this unit to upgrade it from 20 tons to 25 tons. It was then mounted on the Government-design carrier on which the extendible outriggers had been installed. (The addition of the extendible outriggers made it within the realm of possibility that the 20-ton carrier could be used as a 25-ton carrier.)

6. **Power Trains.** The original Technical Data Package allowed for four combinations of three different engines and three different transmissions. Over the years, this shrunk to only one combination of one engine and one transmission. Therefore, it was essential to broaden the power train component procurement base to ensure a more favorable cost and to enhance availability in times of emergency.

A study was made of available commercial engines and transmissions; 39 engine, torque converter, and transmission combinations were considered. Of these, the 7 combinations shown in Table 1 met the required performance and would fit within the existing frame. Weighting of the performance, cost, and design considerations resulted in the selection of Arrangement No. 3, consisting of a Caterpillar Model 3208NA engine and a Twin-Disc Model TD-44-1130 transmission with a Model 8FLW-1400 torque converter. The arrangement is as shown in Figure 2. An extra benefit of this combination was that it reduced weight, partially offsetting weight gained with the outrigger modifications.

The alternate power train was procured and installed in the modified crane for test and evaluation.

7. **Characteristics.** The resulting modified crane is shown in Figure 3. The physical and operational characteristics of the modified crane vs the standard cranes are shown in Table 2.

Table 1. Power Train Combinations That Can Be Used

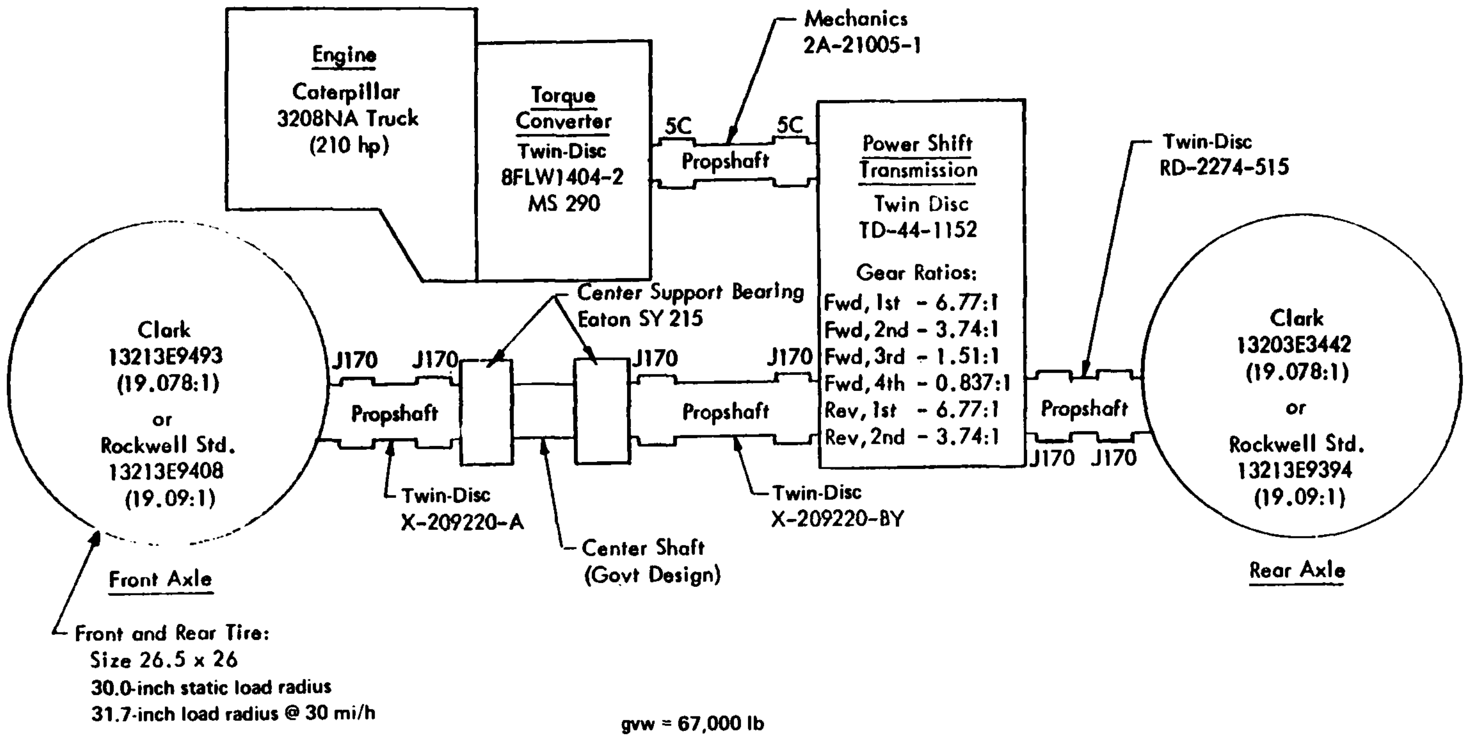
Arr. No.	Power Train Components	Power Train Performance: Top speed RR 20 lb	Power Train Performance: Speed up 40% grade RR 40 lb per ton	Power Train Performance: Gradeability @ 1 mi/h RR 37 lb	Total weight of engine conv. & xmsn	Total cost of engine conv. & xmsn	Remarks
1	Engine: Caterpillar 3208 NA (2800 r/min) Converter: Rockford 13-3.5 Transmission: Oshkosh PT2430-47	32.5 mi/h	1.65 mi/h	60 %	2,630 lb	$8,502	Xmsn has special input speed reducer. Xmsn hangs 2.75 below frame. Frame needs mod.
2	Engine: Cummins V-555-C230 (2800 r/min) Converter: Rockford 14-2.75 Transmission: Oshkosh PT2430-47	33.2 mi/h	1.70 mi/h	62 %	3,115 lb	$8,856	Engine height lowered with optional rear facing air inlet. Xmsn has special input speed reducer. Xmsn hangs 2.75 below frame. Frame needs mod.
3	Engine: Caterpillar 3208NA (2800 r/min) Converter: Twin-Disc 8FLW-1400 Transmission: Twin-Disc TD-44-1130	30.2 mi/h w/lockup	Over 1.53 mi/h	Over 49 %	2,775 lb	$7,011	Xmsn has optional input shaft location and ratios. Xmsn hangs 1.25 below frame.

Table 1. Power Train Combinations That Can Be Used (Cont'd)

Arr. No.	Power Train Components	Power Train Performance: Top speed RR 20 lb	Power Train Performance: Speed up 40% grade RR 40 lb per ton	Power Train Performance: Gradeability @ 1 mi/h RR 37 lb	Total weight of engine conv. & xmsn	Total cost of engine conv. & xmsn	Remarks
4	Engine: Cummins V-555-C230 (2800 r/min) Converter: Twin-Disc 8FLW-1400 Transmission: Twin-Disc TD-44-1130	30.2 mi/h w/lockup	1.53 mi/h	49 %	3,260 lb	$7,365	Engine height lowered with optional rear facing air inlet. Xmsn has optional input shaft location and ratios. Xmsn hangs 1.25 below frame.
5	Engine: International DT466 (2800 r/min) Turbocharged Converter: Twin-Disc 8FLW-1400 Transmission: Twin-Disc TD-44-1130	30.2 mi/h w/lockup	Over 1.53 mi/h	Over 49 %	3,025 lb	$7,292	Engine height lowered with special crossover pipe to turbocharger. Xmsn has optional input shaft location and ratios. Xmsn hangs 1.25 below frame.
6	Engine: Caterpillar 3208NA (2800 r/min) Transmission: Cummins-Sundstrand DMT-25 Transfer Case: Rockwell T-228-D	32 mi/h	Over 1.96 mi/h	Over 100 %	2,806 lb	$7,719	Xmsn shroud must be altered to clear frame.

Table 1. Power Train Combinations That Can Be Used (Cont'd)

Arr. No.	Power Train Components	Power Train Performance: Top speed RR 20 lb	Power Train Performance: Speed up 40% grade RR 40 lb per ton	Power Train Performance: Gradeability @ 1 mi/h RR 37 lb	Total weight of engine conv. & xmsn	Total cost of engine conv. & xmsn	Remarks
7	Engine: Cummins V-555-C230 (2800 r/min) Transmission: Cummins-Sundstrand DMT-25 Transfer Case: Rockwell T-228-D	32 mi/h	1.96 mi/h	Over 100 %	3,296 lb	$8,073	Engine height lowered; with optional rear facing air inlet. Xmsn; shroud must be altered to clear frame.



This power train is designed to meet the following performance levels:

a. 30 mi/h minimum on a level road surface having a rolling resistance of 20 lb per 1000 lb of gvw.
b. 1.75 mi/h minimum up a 40 percent grade on a road surface having a rolling resistance of 20 lb per 1000 lb of gvw.

Figure 2. Arrangement of the Caterpillar/Twin-Disc power train.

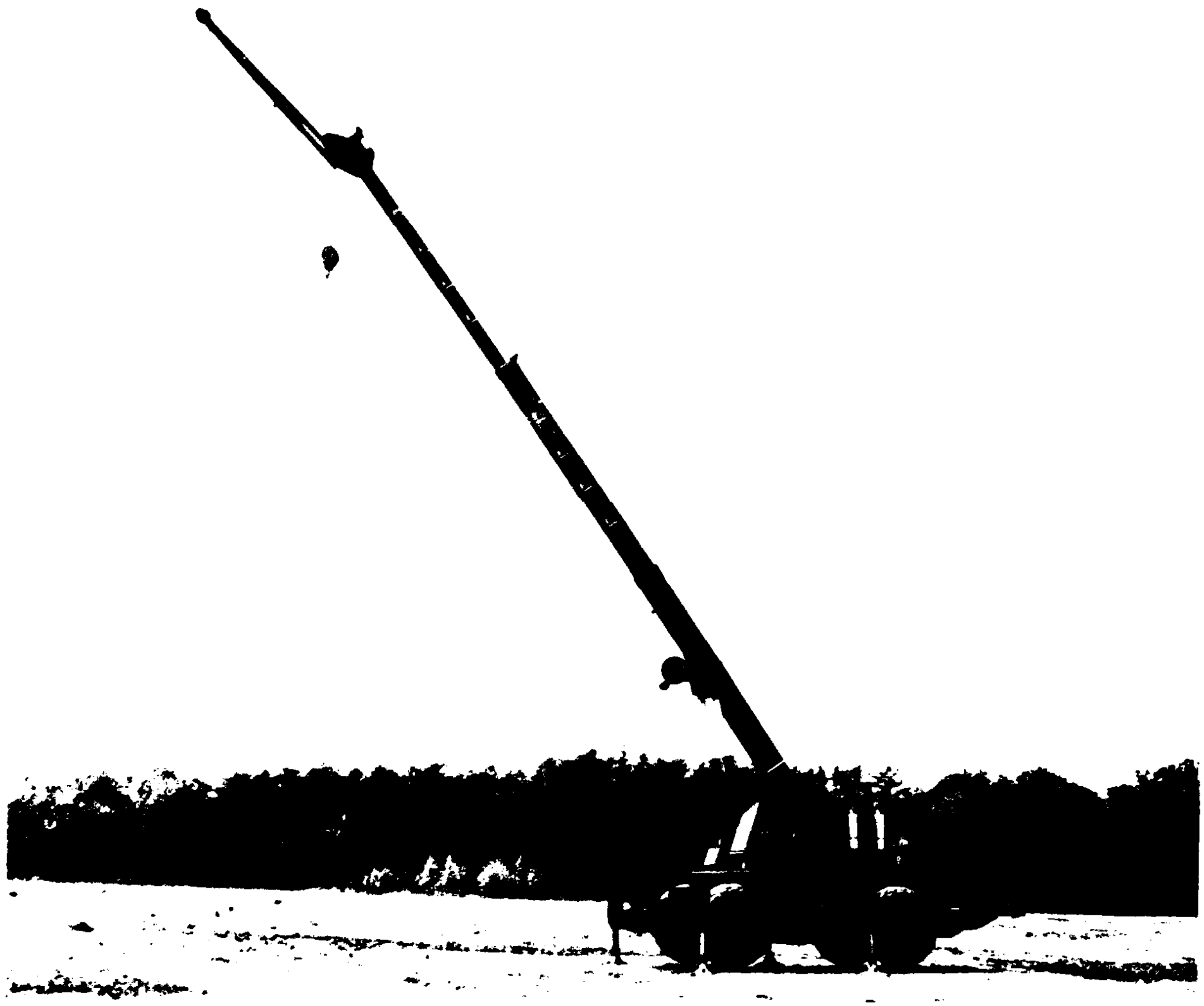


Figure 3. Modified rough-terrain crane.

Table 2. Comparison of Rough-Terrain Cranes

a. Physical Characteristics

Manufacturer	AH&D	P&H	Modified Crane
Model	2385	M32ORT	–
Rating	20 tons	20 tons	25 tons
Length and type of boom	30 ft/lattice	30 ft/lattice	26-60 ft/telescoping
Overall length	44.75 ft	44.75 ft	34.5 ft
Width	10.5 ft	10.5 ft	10.5 ft
Height	11.2 ft	11.2 ft	11.2 ft
Total weight	63,550 lb	66,740 lb	67,000 lb
Superstructure Engine/hp	Cummins Model 100	Detroit Diesel Model 97	Cummins Model 130
Carrier Engine/hp	Cummins Model 265	Cummins Model 265	Cat Mod 3208NA 210
Converter	Clark	Clark	Twin-Disc
Transmission	Clark	Clark	Twin-Disc

b. Operational Characteristics

Model	2385	M32ORT	–
Outriggers	Fixed	Fixed	Extendible Beam
Span	9 ft 4 in.	9 ft 4 in.	15 ft
Drive	2/4-wheel	2/4-wheel	2/4-wheel
Steering	4-wheel	4-wheel	4-wheel
Max. speed	30 mi/h	30 mi/h	35 mi/h
Max. gradeability	40%	40%	49%
Fording depth	48 in.	48 in.	48 in.
Rated Lifting Capacity	20 tons @ 10 ft	20 tons @ 10 ft	25 tons @ 12 ft

III. TESTS AND TEST RESULTS

8. **Tests.** Tests of the modified crane were conducted to determine conformance to Specification MIL-C-52341, except where the specification is not applicable to hydraulic superstructures. Additional tests were conducted when considered appropriate because of the nature of the design changes. Specific tests performed were:

a. **Outrigger Beam Tests.** The outrigger beams were bench tested prior to installation on the crane to determine their ability to withstand the design loads of 50,000 pounds extended and the equivalent of 125 percent of rated load over the rear of the crane.

b. **Lifting Capacity Tests.** The lifting capacity tests in MIL-C-52341 are tailored to Industry practices for lattice-boom cranes in that the rated load is 85 percent of tipping load. However, Industry practice for hydraulic cranes with telescoping (cantilevered) booms is that rated load can be limited by either tipping or structural stress. Therefore, the superstructure was tested in accordance with Society of Automotive Engineers (SAE) J1063 Method of Test - Cantilevered Boom Crane Structures, rather than to Specification MIL-C-52341; however, the carrier was tested to the requirement of the specification that stresses it is not to exceed 60 percent of the yield strength of the material, which allows for a stress of 60,000 lb/in^2. A total of 166 strain gages were installed: 106 on the carrier frame and axles, 4 on the boom base section, 32 on the boom, 14 on the boom point, and 10 on the jib. An additional test was performed to determine the capability to lift a fully loaded standard military container weighing 44,800 pounds and place it on a transporter.

c. **Power Train Performance Tests.** Tests were conducted to determine the ability of the crane with the new power train installed to meet the performance requirements of MIL-C-52341. These included travel speed, gradeability, steering, and 1000-mile travel tests.

9. **Test Results.** Test results were as follows:

a. **Outrigger Beam Test.** The outriggers withstood the design loads without permanent deformations or failure during the bench tests.

b. **Lifting Capacity Tests.** Details of the strain gage tests are available in "Strain Gage Test Report (SG-1050-78)" dated 15 June 1978. Analysis of strain gage results on the superstructure, including boom, show that stress levels are within allowable limits if loads are within the limits of the load chart shown in Table 3. Maximum stress recorded on the carrier frame was 56,000 lb/in^2 which is within the allowable 60,000 lb/in^2. The crane was capable of loading the 44,000-pound container as shown in Figures 4 through 7.

Table 3. Load Capacity Chart for Modified Crane (26- to 50-Foot Boom)

Over Rear/Side With Outriggers												
Radius in Feet	Boom Angle and Boom Length											
	26-ft		34-ft		40-ft		46-ft		52-ft		60-ft	
10	58°	50,000	66°	47,900	70°	38,000	74°	35,200				
12	53°	50,000	63°	43,500	67°	34,100	71°	31,400	74°	27,200		
15	44°	46,700	57°	38,200	62°	29,600	67°	26,800	70°	23,000	75°	20,000
20	24°	35,000	46°	31,100	54°	23,900	60°	21,400	64°	18,100	68°	15,000
25			33°	25,900	44°	20,000	52°	17,700	58°	14,900	63°	12,000
30					33°	17,100	44°	15,100	51°	12,600	57°	10,000
35					15°	15,000	34°	13,100	43°	10,800	51°	8,000
40							19°	11,600	34°	9,400	45°	6,000
45									22°	8,300	38°	5,000
50											28°	4,500
55											14°	4,000

NOTES: Radius of load is the horizontal distance from a projection of axis of rotation before loading to the center of vertical hoist line or tackle with load applied. Boom length is measured from centerline of boom pivot pin to centerline of boom point sheave along the longitudinal axis of the boom.

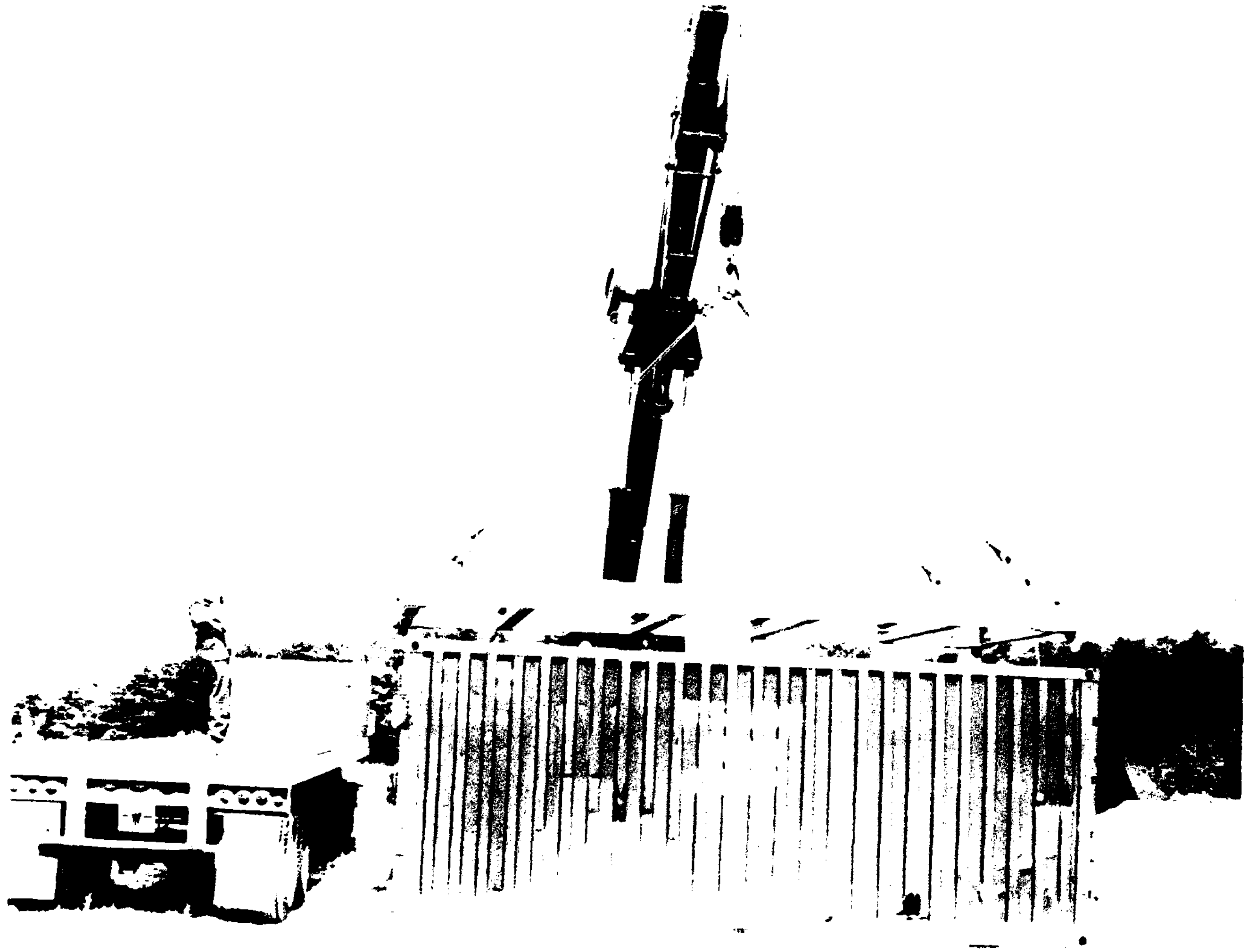


Figure 4. MILVAN awaiting transfer.

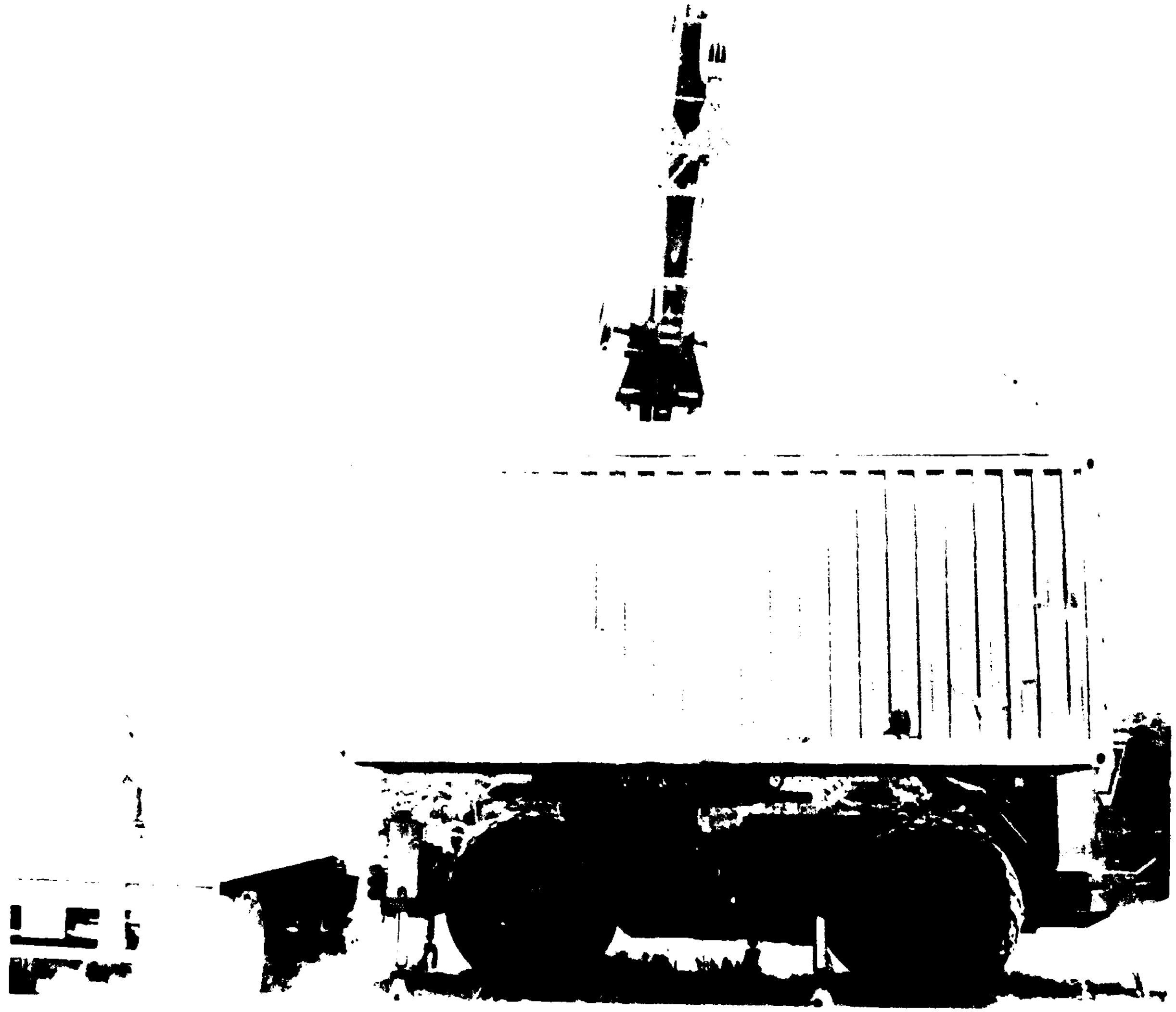


Figure 5. Modified RT crane lifts MILVAN.

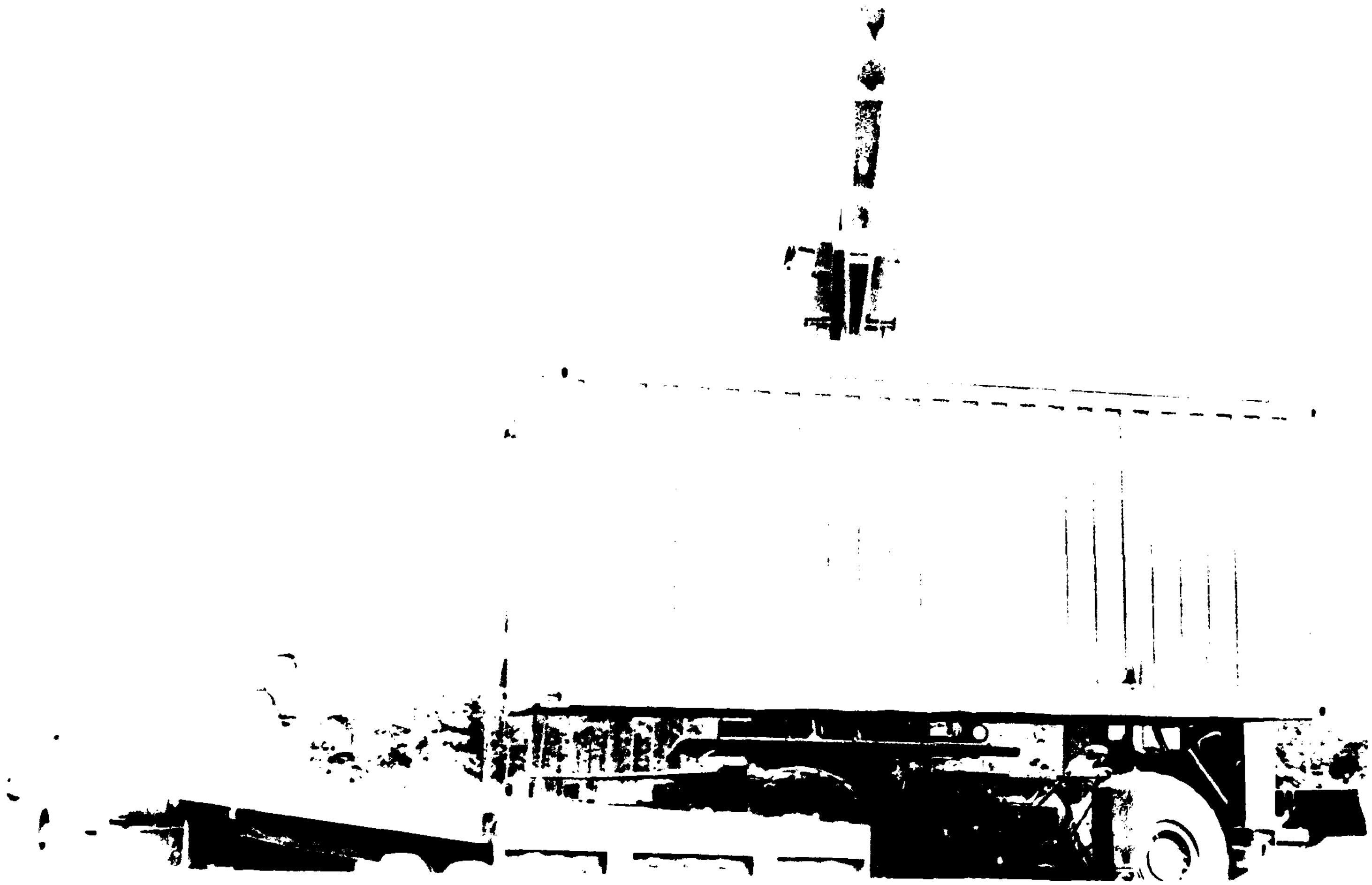


Figure 6. Modified RT crane transfers MILVAN.

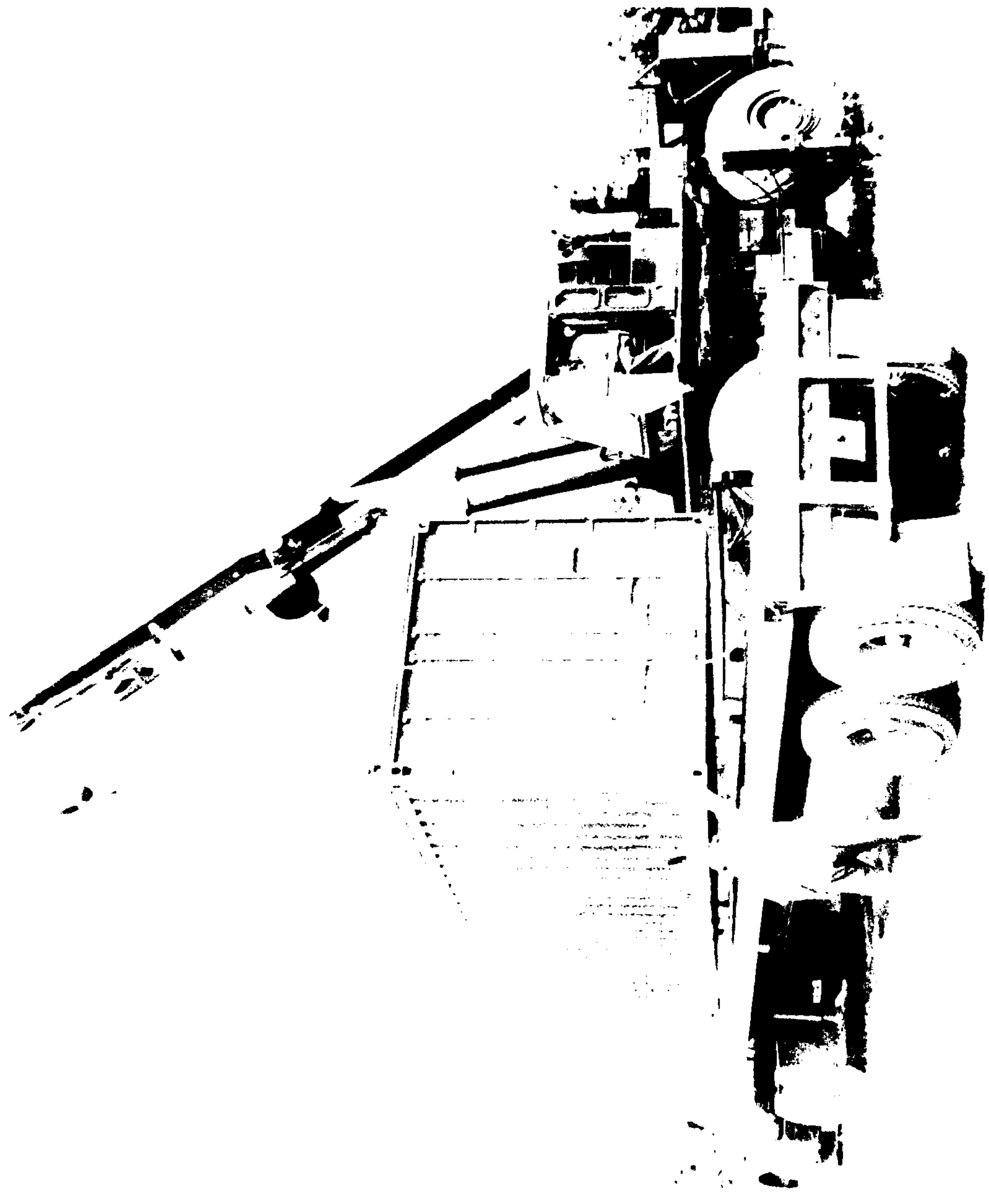


Figure 7. Modified RT crane positions MILVAN on trailer.

c. **Travel Speed Tests.** Based on the average elapsed time over a fixed-distance course for 6 runs, the average speed was 35.91 mi/h compared to 30 mi/h required.

d. **Gradeability.** The crane safely ascended a 40-percent longitudinal slope at an average speed of 2.15 mi/h vs 1.75 mi/h required by the Specification. It safely descended the same slope. Additional tests showed that the crane can safely ascend a 49.75-percent longitudinal slope at a speed of 1.56 mi/h.

e. **Steering Tests.** The crane successfully completed the steering test by negotiating a 100-foot circle in 2-wheel steering and a 50-foot circle in 4-wheel steering in both the left and right directions.

f. **1000-Mile Travel Test.** The crane completed 500 miles of travel over secondary roads without difficulty. After approximately 394 miles of cross-country travel, the carrier engine failed and the test was halted. The engine was removed and returned to Caterpillar for repair. They stated that the cause of failure was loose piston rods. The repaired engine was reinstalled, and the crane was operated for an additional 1,018 miles over secondary roads and cross country with no further difficulties or failures.

10. **Discussion of Test Results.** Post test inspection of the crane did not reveal any signs of structural failure or permanent deformations of material. This, along with strain gage results, indicates that the design changes are in themselves adequate and do not have a deleterious effect on the other members and components.

The extendible outriggers eliminated any real or psychological problems concerning crane stability when lifting rated loads over the side. However, in that they provided adequate stability for lifting 25-ton loads over the side, the outriggers may prove to prevent a hazard in the event that they are used in conjunction with the 20-ton mechanical superstructure. The extendible outriggers increase the tipping point which, if Industry standards are used, effectively increases the rated load. It is highly doubtful that the commercial 20-ton mechanical superstructures and Military design lattice booms used are structurally adequate for this increase. In addition, many times the operator does not know the weight of the load he is lifting and consequently depends on his feeling of crane stability to determine if he can lift the load at the desired radius. The removal of this indicator could result in damage to the superstructure. The choice of a 90-inch extension capability for the outriggers was a matter of judgement during design; test results indicate that a reduced extension length would be more appropriate for use with the current mechanical superstructure. Therefore, further study and minor design modifications would be required prior to use in new procurements of the crane with a 20-ton mechanical superstructure.

Observation of operation of the modified crane showed that the advantages of a hydraulic crane, such as ease of operation, improved control, smoothness of movement, and variable boom length, were the same for the rough terrain crane as for truck-mounted cranes. This was as should have been expected for the type of operations performed. However, it should be noted that functions such as clamshell and drag line operations, where a mechanical crane could be expected to be better, were not performed.

The tests demonstrated conclusively that the current 20-ton rough-terrain carrier design if modified to include the extendible outriggers is satisfactory from structural and operational standpoints for use as a carrier for a 25-ton hydraulic superstructure. The carrier with the current outriggers or with the extendible outriggers would be suitable for use with a 20-ton hydraulic superstructure. However, it would be desirable to incorporate extendible outriggers to overcome past field complaints concerning stability, since the stability would be essentially the same regardless of whether a hydraulic or mechanical superstructure is used.

The fact that there was one failure of the Caterpillar Model 3208NA engine is not considered of consequence in that this engine has widespread commercial use in truck applications with a successful history. Therefore, the failure experienced is considered to be a random failure.

Observations and operator comments (in addition to the specific test data) showed that the alternate power train provides equal or better overall performance when compared to the power trains in the fielded cranes.

IV. CONCLUSIONS

11. **Conclusions:** It is concluded that.

a. The hydraulic outriggers increase stability of the crane when lifting loads over the side and are suitable from both structural and operational standpoints for use with superstructures rated up to 25 tons.

b. The expansion distance of the extendible outriggers should be reduced for use with 20-ton superstructures; further study is required to determine ideal expansion.

c. The 20-Ton Rough-Terrain Crane carrier with the addition of extendible outriggers is suitable for use with hydraulic superstructures of up to 25-ton rated capacity.

d. The operation of a hydraulic superstructure on the rough-terrain crane offers the same advantages and disadvantages (when compared to a mechanical superstructure) as those for a truck crane.

e. The alternate power train consisting of the Caterpillar engine and Twin-Disc transmission is suitable for incorporation into Technical Data Packages and will broaden the procurement base.

f. It is feasible to provide a 25-ton hydraulic rough-terrain crane through modification of the Technical Data Package for the 20-Ton Rough-Terrain Crane.

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